ing dependence on charge to mass ratio, Z/A:

$$\frac{\mu_E}{\mu_\infty} = \exp\left[-\frac{Z}{A}\left(\frac{1}{\gamma^{n-1}\beta^n}\right)K(t)\right],$$

where μ_E and μ_∞ are the respective particle densities at earth and outside the solar system, and β is the velocity of the particle in units of the velocity of light, $\gamma = (1-\beta^2)^{-1/2}$; $K(t)$ is a constant depending only on time t, and is taken to be unity; $n = 1$.

[15] Same form as in Ref. 14 except $n = 2$. Again we take $K(t) = 1$.

[16] This is concluded from the fact that there is no large time variation in this period for the $[\mathrm{He}^3 + \mathrm{He}^4]$ spectrum as is evident in Fig. 2. The greatest change in the proton flux observed on IMP-III within the time interval 20 May–20 September was less than 10% and, hence, represents the upper limit for the change of He^3 fluxes over this time period.

COSMIC BLACK-BODY RADIATION AT $\lambda = 2.6$ mm*

George B. Field and John L. Hitchcock

Astronomy Department, University of California, Berkeley, California

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Penzias and Wilson[1] have shown that at $\lambda = 7.4$ cm there exists an approximately isotropic background radiation component whose equivalent black-body temperature is 3.5 ± 1°K; Roll and Wilkinson[2] have obtained 3.0 ± 0.5°K at $\lambda = 3.2$ cm. In this Letter we obtain values in the range 2.7 to 3.4°K at $\lambda = 2.6$ mm by measurements of the spectra of the two stars ζ Ophiuchi and ζ Persei, further supporting the suggestion by Dicke et al.[3] that the universe is filled with 3°K black-body radiation as a result of processes occurring early in cosmic history. We shall show that this postulate is the best way to explain the data.

It has been known for many years that absorption lines in the spectrum of ζ Oph due to CN molecules in interstellar space exhibit excitation of the $J = 1$ rotational state corresponding to a temperature, T_E, of over 2°K[4] as indicated by the ratio of the $R(1)$ and $R(0)$ lines of the transition $B\,^2\Sigma^+ - X\,^2\Sigma^+$ (0, 0), at $\lambda = 3874.00$ Å and $\lambda = 3874.61$ Å, respectively.[5] Pure rotational absorption at $\lambda = 2.6$ mm could account for the excitation, but it was shown,[6] also many years ago, that dilute starlight, which has a spectral energy distribution corresponding to about 10^4 °K, is too weak at $\lambda = 2.6$ mm to give a population ratio N_1/N_0 much greater than 10^{-12}, whereas 0.3 was observed. Interest in this problem has again arisen, after a lapse of 25 years, because of the radio measurements mentioned above.

Dr. G. H. Herbig kindly placed at our disposal six plates of ζ Oph (2 Å/mm) and one of ζ Per (1.3 Å/mm), which he obtained at the Coudé spectrograph of the Lick Observatory 120-inch telescope. Our measurements were supplemented by independent measurements of the ζ Oph data by Dr. Herbig. The equivalent widths found were $W_0 = 9.20 \pm 0.2$ mÅ and $W_1 = 3.37 \pm 0.2$ mÅ for ζ Oph, and $W_0 = 10.9 \pm 1.1$ mÅ and $W_1 = 3.5 \pm 0.7$ mÅ for ζ Per. For ζ Oph the quoted error is the scatter range of the measurements, while for ζ Per it is estimated from the grain noise on the microphotometer tracing. Since $N_1/N_0 = \lambda_0^2 f_0 W_1/\lambda_1^2 f_1 W_0$ and $f_1/f_0 = \frac{2}{3}$, $N_1/N_0 = 0.55 \pm 0.05$ in ζ Oph and $N_1/N_0 = 0.48 \pm 0.15$ in ζ Per. Since $g_1/g_0 = 3$ and $h\nu/k = 5.47$°K for the $J = 0 \rightarrow 1$ transition, $T_E = 3.22 \pm 0.15$°K in ζ Oph and $T_E = 3.0 \pm 0.6$°K in ζ Per. These data, derived on the assumption that the lines are unsaturated, are subject to uncertainty on that account. However, even if the lines are really as narrow as the narrowest line ever found in interstellar space – 0.3 km/sec rms – T_E would still be 2.7°K. We conclude that T_E is between 2.7 and 3.4°K for both stars.

Only recently a theory of the origin of interstellar CN molecules has appeared[7]; the observed densities can be explained in spite of the short lifetime toward photodissociation if chemical exchange reactions are postulated to occur at the surfaces of interstellar grains. According to the theory, production occurs in H I (neutral hydrogen) regions. For purposes of calculation we shall assume that the CN is located in typical H I regions, where $N_\mathrm{H} = 10$ cm^{-3} and T_K (kinetic) = 100°K. The radiation field due to stars at 3900 Å is equivalent to that of the sun at 10^4 A.U.[8]

We have considered excitation due to collisions with H atoms, fluorescence, and pure rotational absorption. Collisions give $N_1/N_0 = g_1C_{10}/g_0(C_{10}+A_{10})$, since $T_K \gg h\nu/k$, where C_{10} and A_{10} are the collisional and radiative rates of de-excitation. According to Takayanagi and Nishimura,[9] $C_{10} = 3.5\times10^{-10}$ sec^{-1}. A_{10} depends upon the value of the electric dipole moment, which unfortunately has not been securely determined in the laboratory. Arpigny[10] has shown from a study of the observed fluorescence of CN in comets that $A_{10} = 7.4\times10^{-6}$ sec^{-1}, corresponding to $\mu = 1.2$ Debye unit. Apparently collisional excitation is far too weak ($N_1/N_0 = 1.4\times10^{-4}$).

Fluorescent processes due to 3900-Å stellar radiation can be evaluated using Arpigny's results. We obtain $N_1/N_0 = 1.3\times10^4/r^2$, where r is the effective distance to the star in A.U. Since the effect of adding the radiation from all stars is equivalent to $r = 10^4$, $N_1/N_0 = 1.3\times10^{-4}$, again negligible.

The 2.6-mm quanta required for rotational excitation can originate from stars, bremsstrahlung by ionized interstellar gas, and nonthermal radio sources. Stars give $N_1/N_0 = 10^{-12}$ as mentioned above, while bremsstrahlung gives $N_1/N_0 = 2\times10^{-8}N_e{}^2L$, the units of $N_e{}^2L$ being cm^{-6} pc. An ionized region surrounds ζ Oph itself and there $N_e{}^2L = 500$, giving only 10^{-5} for N_1/N_0, even for CN very close to the star. Even the regions with the highest known values of $N_e{}^2L$ fail by two orders of magnitude to give the observed N_1/N_0. Since nonthermal sources are even weaker at millimeter wavelengths than bremsstrahlung sources, they also fail.

The possibility that the CN is located in atypical regions has been suggested.[11] According to the accompanying paper by Thaddeus and Clauser,[12] relatively high densities of 1-eV electrons, coextensive with the CN, could cause excitation via collisions. For example, the CN molecules could in principle be located in the ionized region around ζ Oph. Since $N_e = 100$ cm^{-3} is required, such a region cannot be more than 0.5 pc across, in order not to violate $N_e{}^2L = 500$. Fluorescence near the hot stars themselves would excite the CN if it were less than 0.05 pc from them, but the molecular lifetime would be very short under such conditions. It seems very unlikely that such special conditions would occur in the same degree near the two stars ζ Oph and ζ Per, as required to explain the similar values of T_E.

Since the excitation cannot be explained by conventional mechanisms in either typical or atypical regions, we believe that the postulate of Dicke et al.[3] is the best way to explain it. The postulated source is uniform over the galaxy, as required by the fact that the stars observed are in opposite parts of the Milky Way. N_1/N_0 is given by $(g_1/g_0)[J_\nu'/(1+J_\nu')]$, where $J_\nu = 2h\nu J_\nu'/\lambda^2$ is the specific mean intensity. If the effective black-body temperature T_R is defined by $J_\nu' = [\exp(h\nu/kT_R)-1]^{-1}$, it follows that $T_E = T_R$, whence $T_R = 2.7$-3.4°K. The present measurements therefore verify the black-body nature of the spectrum over a 28:1 wavelength interval, extending close to the black-body maximum at 1-mm wavelength.

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